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PRELIMINARY CALIBRATION AND TEST RESULTS
FROM THE NATIONAL TRANSONIC FACILITY

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The highlights of the National Transonic Facility (NTF) operating experience are shown in the figure below.

- CHECKOUT OF MAJOR SYSTEMS

- OPERATING ENVELOPE COVERED
- MODIFICATION TO HEATERS ON MODEL ACCESS SYSTEM

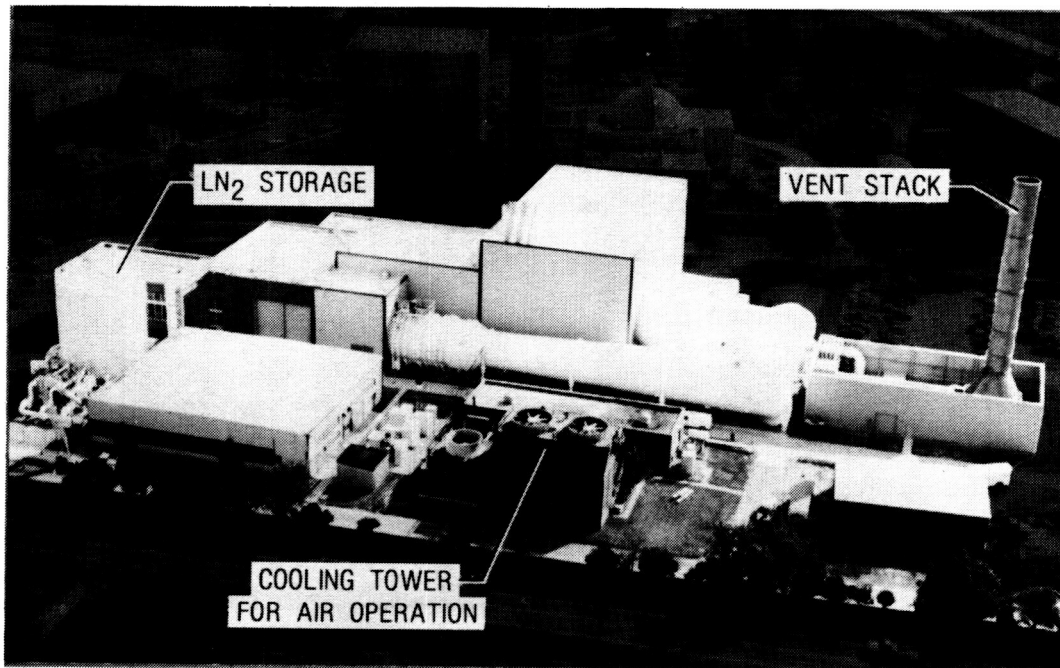
- INITIAL CALIBRATION

- MACH NUMBER UNIFORMITY
- TOTAL TEMPERATURE DISTRIBUTION
- TOTAL PRESSURE DISTRIBUTION

- INITIAL MODEL TESTS

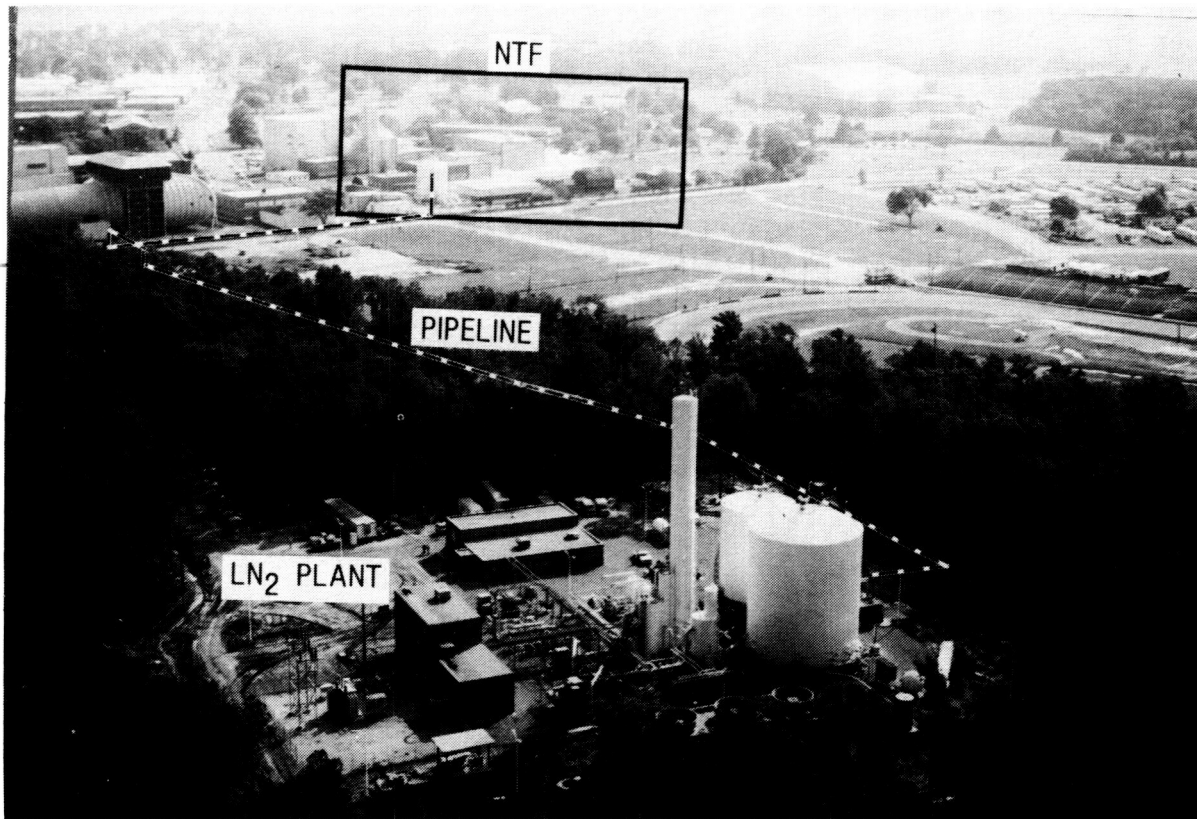
- PATHFINDER I
- SPACE SHUTTLE

An aerial view of the National Transonic Facility (NTF) site, viewed from the back side, is presented. The large bulk storage nitrogen tank on the left and the vent stack at the right of the tunnel are used to support the cryogenic mode of operation. The cooling tower in the foreground is used with a water-cooled heat exchanger inside the tunnel to support the air mode of operation. The high bay building in the background houses model preparation bays and shop area on the first floor and the control room and tunnel test section entrance on the second floor. The design performance capability is a Mach number range of 0.2 to 1.2, pressure range of 1 to 8.8 atm, and temperature range of 77 to 339K. This will produce a maximum Reynolds number of 120 million at a Mach number of 1.0 based on a chord length of 0.249 meters.



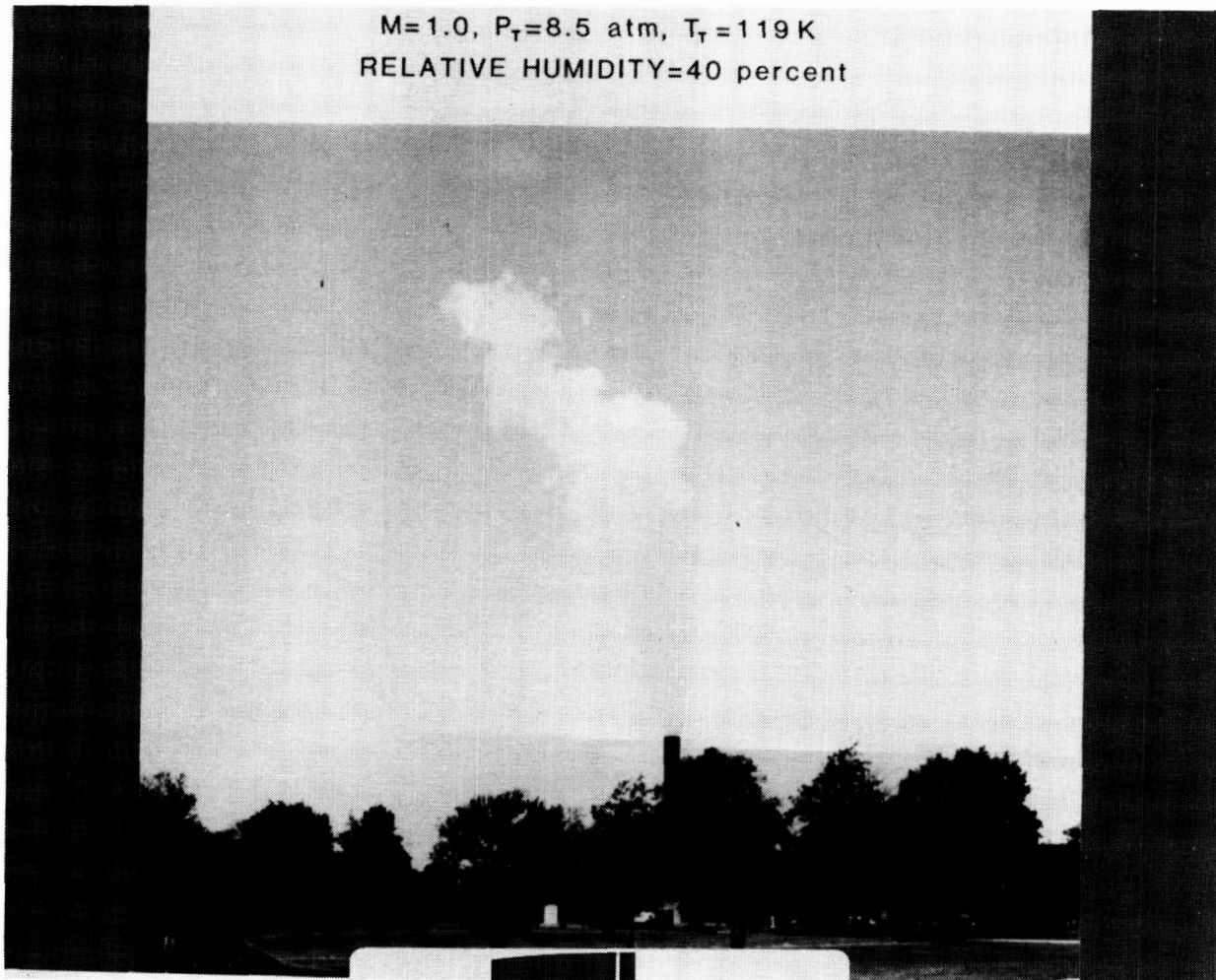
LN₂ PLANT

The majority of the nitrogen is supplied to the onsite 946 cubic meter storage tank by pipeline from a commercial air separation plant. This system has been operational since January 1983 and supplied most of the liquid nitrogen for the NTF during checkout. The onsite storage tank can also be filled from mobile truck units.



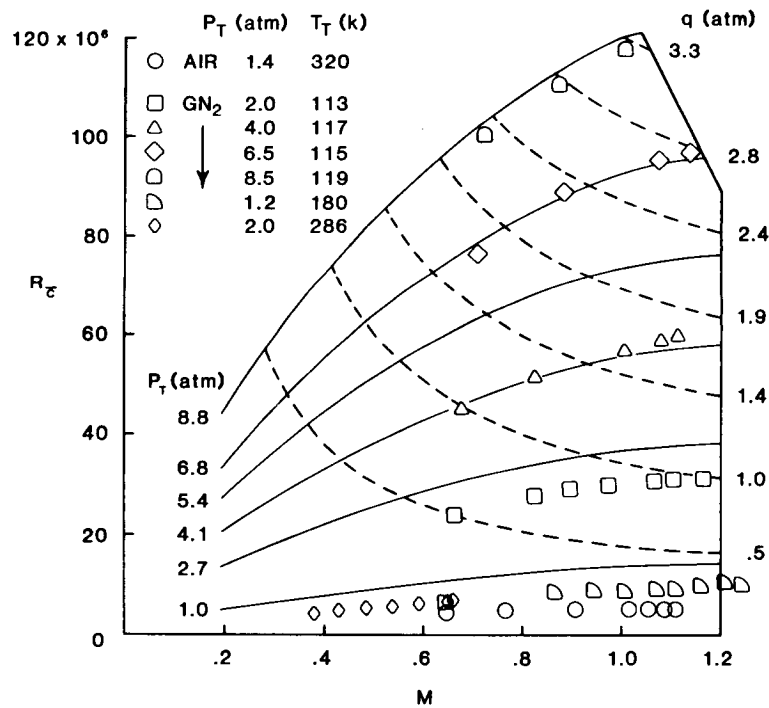
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The safe venting of the gaseous nitrogen to the atmosphere is closely monitored during all cryogenic test runs. A fan/ejector system mixes ambient air with the gaseous nitrogen expelled from the tunnel in a vent stack 37 meters high. The mixing ratio in the stack is at least one to one under all conditions so that the oxygen content at the stack exit is at least ten percent by volume. The temperature is still low at the exit so that the size of the visible plume emitted is dependent on the atmospheric humidity and wind conditions.



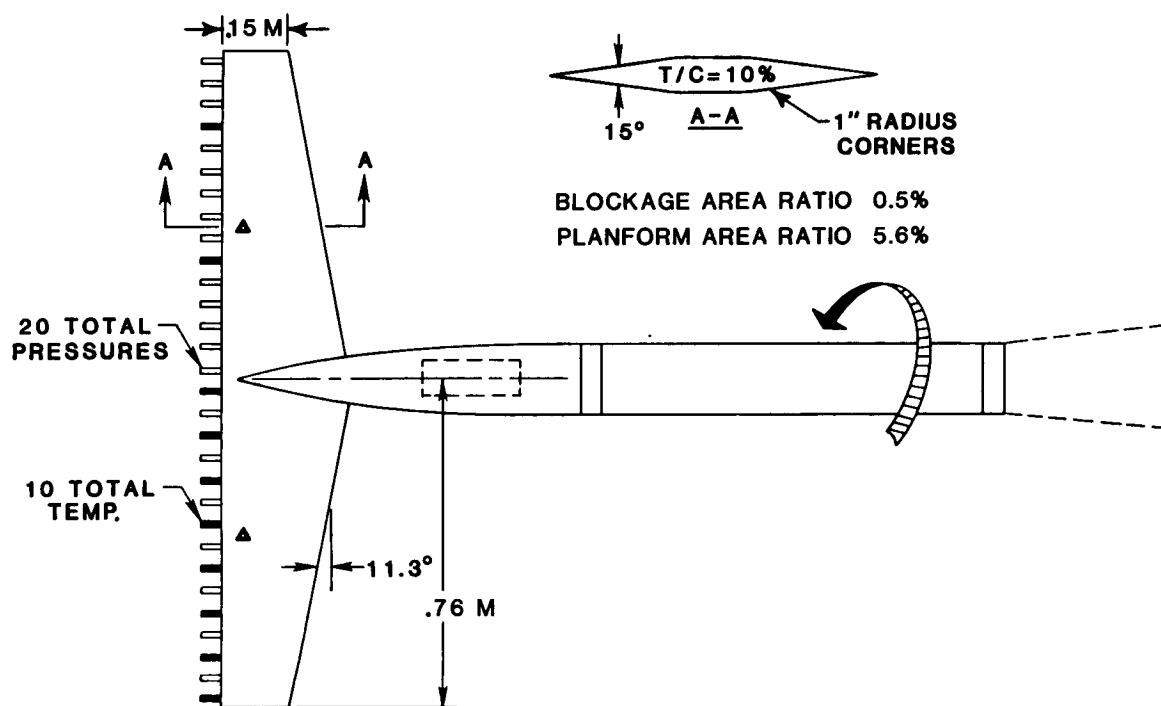
REYNOLDS NUMBER ENVELOPE

The maximum operating envelope showing Reynolds number as a function of Mach number is presented and gives a fairly complete picture of the range over which the NTF has been operated. The boundary lines and the lines of constant total and dynamic pressure correspond to operation at minimum cryogenic temperature. The maximum Mach number achieved thus far in the checkout and calibration phase was 1.22. This Mach number was obtained in nitrogen at a pressure of 1.2 atm and at a temperature of 180K. In air, the maximum Mach number was 1.12 at a pressure of 1.4 and at a temperature of 320K.



SURVEY RAKE

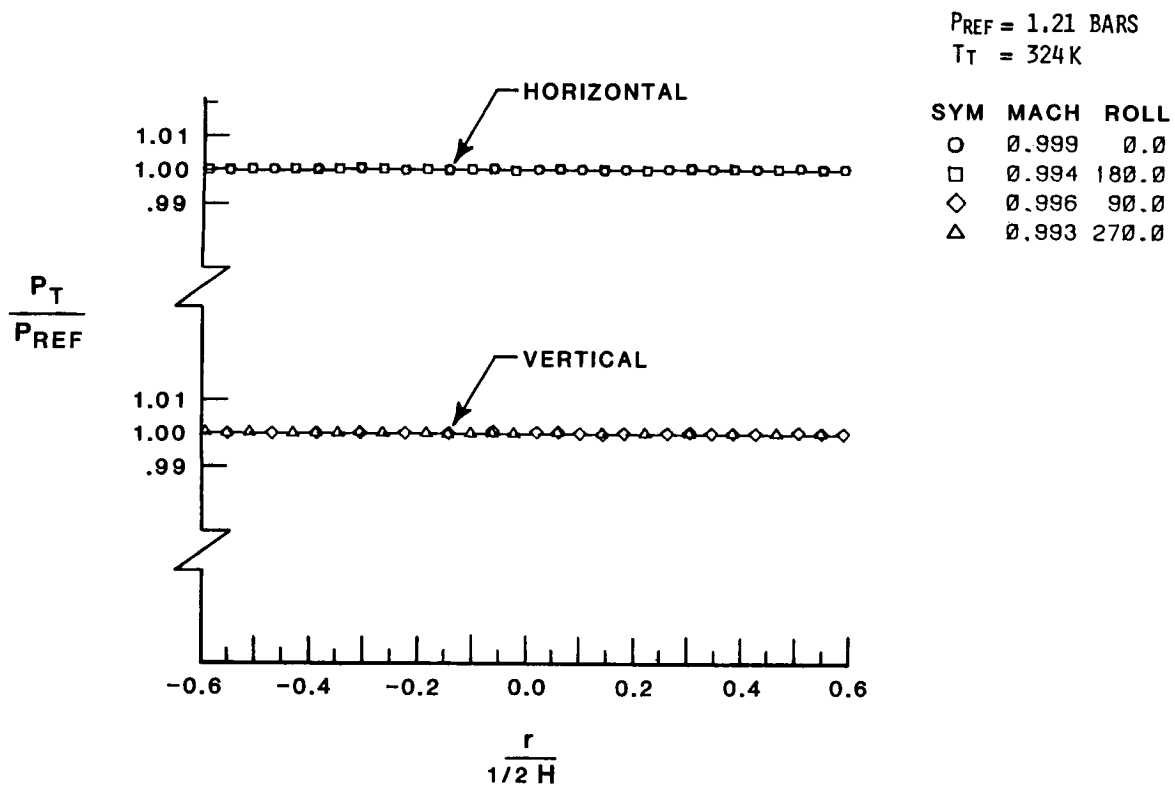
The survey rake was utilized to determine total pressure and temperature uniformity in the test section. The rake had an array of twenty total pressures and ten total temperatures and was mounted in the NTF roll coupling (internal to the model support arc sector) to provide roll capability of $\pm 180^\circ$. The front of the rake was located at the arc sector center of rotation (station 13). The pressures were measured with the ESP system, and the thermocouples utilized an onboard reference junction to enhance measurement accuracy. The absolute level of the thermocouple measurements was anchored by a platinum resistance thermometer mounted in the settling chamber of the tunnel.



TOTAL PRESSURE DISTRIBUTION - 324K

Typical variations of total pressure across the test section normalized by the reference total pressure for air at 324K are presented. The reference line faired through the data is for a condition of zero gradient. It will be noted from an inspection of the data that a pressure gradient is not detectable in either the horizontal or vertical direction. Data taken at other radial cuts across the test section indicate the same result.

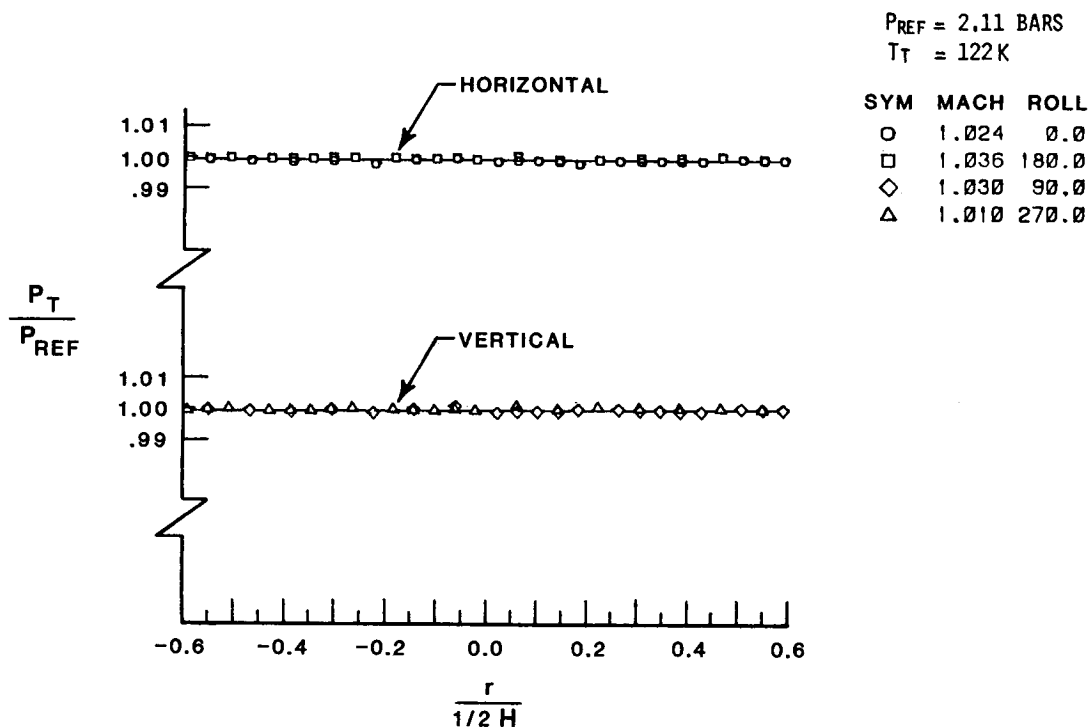
ROTARY RAKE PRESSURES



TOTAL PRESSURE DISTRIBUTION - 122K

Typical variations of total pressure across the test section normalized by the reference total pressure for cryogenic operation at 122K are presented. The reference line faired through the data is for a condition of zero gradient. It will be noted from an inspection of the data that a pressure gradient is not detectable in either the horizontal or vertical direction. Data taken at other radial cuts across the test section indicate the same result.

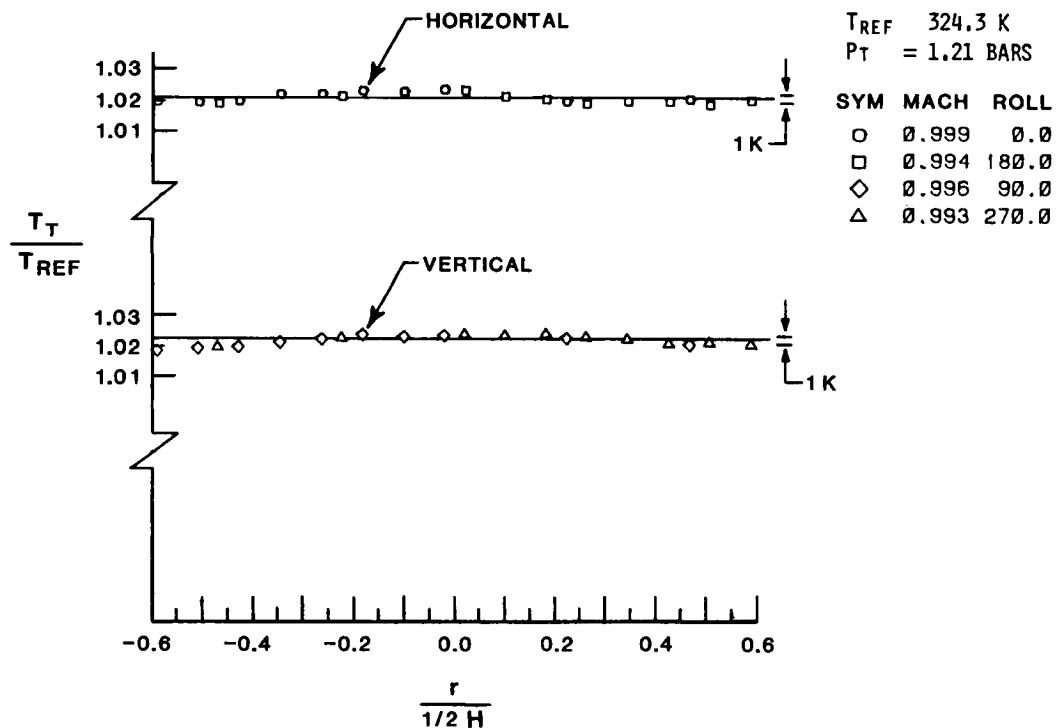
ROTARY RAKE PRESSURES



TOTAL TEMPERATURE DISTRIBUTION - 324K

Typical variations in total temperature across the test section normalized by the reference total temperature are presented. The data were taken in air at 324 Kelvin using the cooling coil. The reference lines represent zero gradient. The distribution of data about this line is within plus or minus 1 Kelvin.

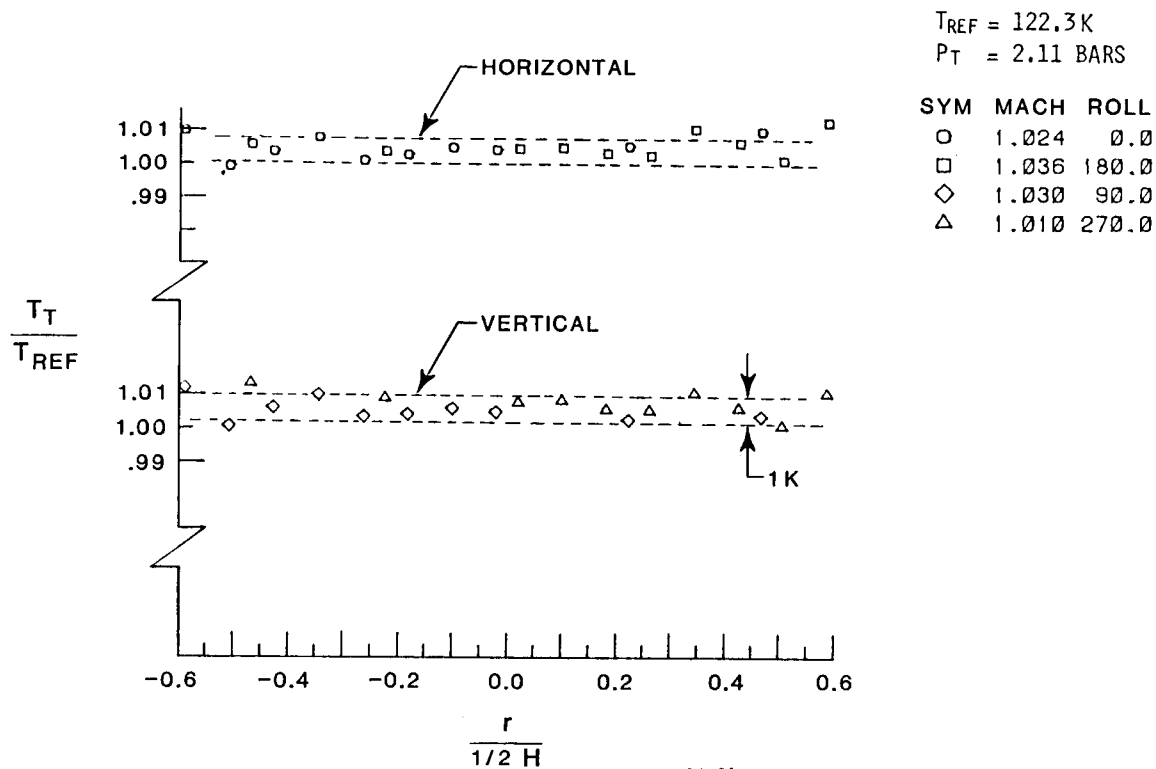
ROTARY RAKE TEMPERATURES



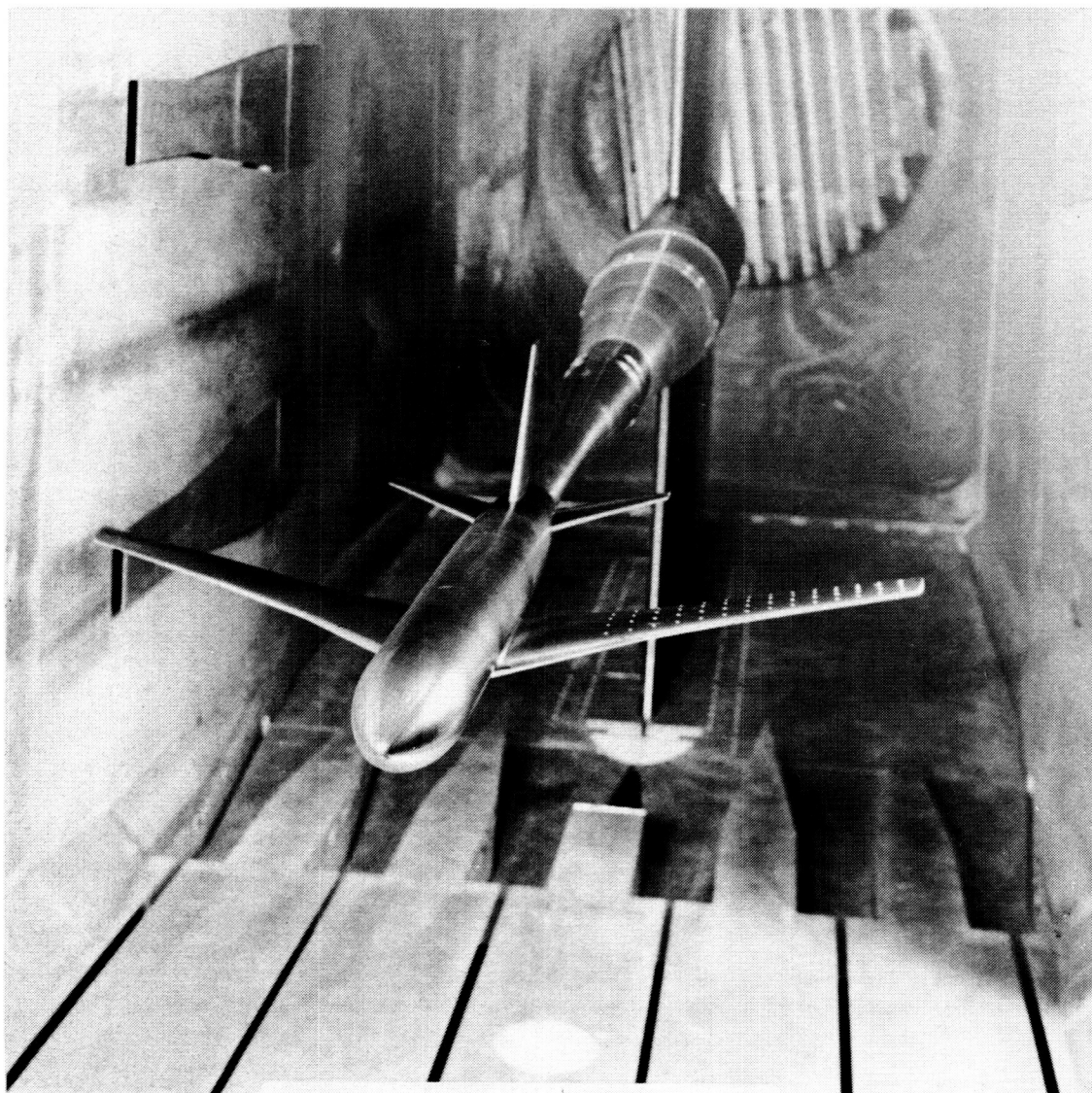
TOTAL TEMPERATURE DISTRIBUTION - 122K

Typical variations in total temperature across the test section normalized by the reference total temperature are presented. The data were taken in the cryogenic mode using the liquid nitrogen injectors for cooling. These data generally fall within a band of plus or minus 0.5 Kelvin. It should be noted that the total temperature ratio is slightly higher than unity. This is due to an offset in the reference temperature junction which was not corrected during the test. This is not important for this discussion since the temperature uniformity across the test section was the primary item of interest and is not affected.

ROTARY RAKE TEMPERATURES

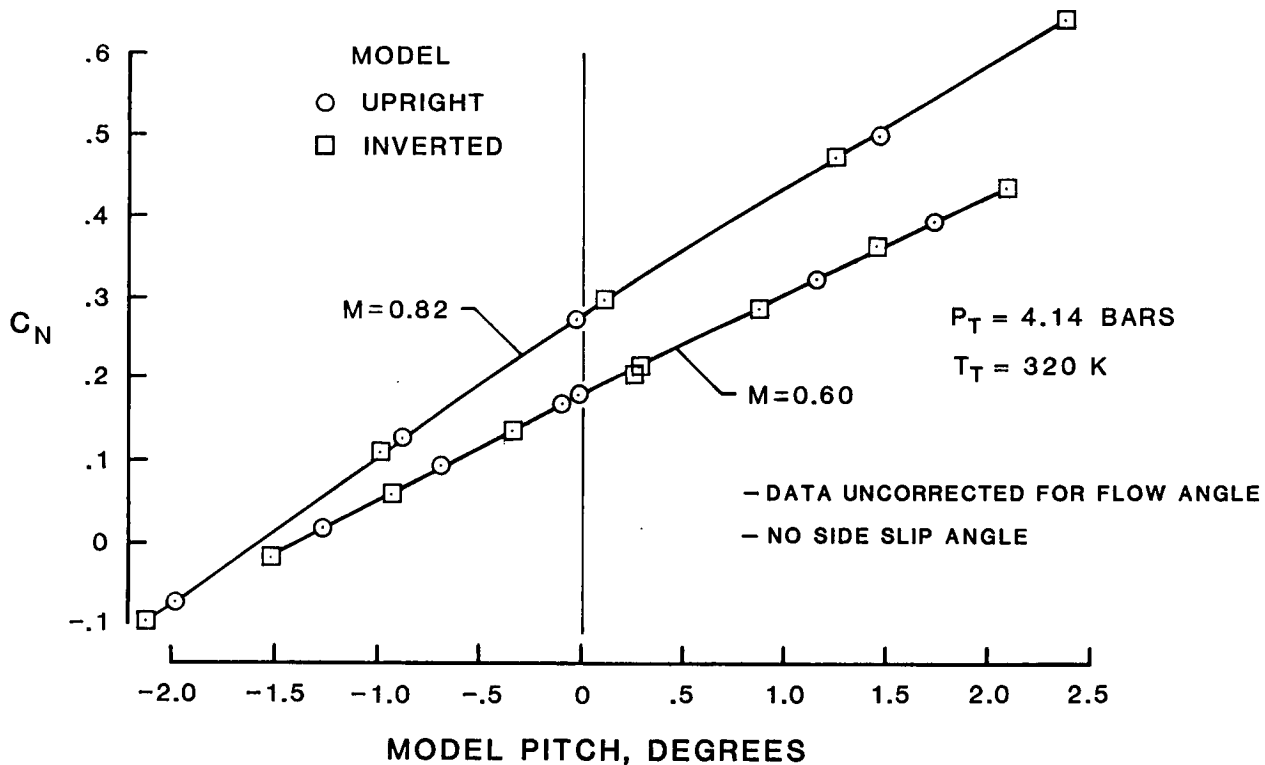


The model represents a generic transport with supercritical airfoil and aspect ratio of 9.8. Spots on the left wing are targets used in the checkout of the model deformation system.



TUNNEL FLOW ANGLE

The tunnel flow angularity was investigated using the Pathfinder I model to obtain an integrated value of the flow angle by testing the model upright and inverted. The variation of normal force coefficient with model angle of attack for the model upright and inverted is shown for Mach numbers of 0.60 to 0.82. The near perfect agreement between the upright and inverted runs at both Mach numbers indicates that a correction for flow angle in the NTF at these test conditions will not be required.

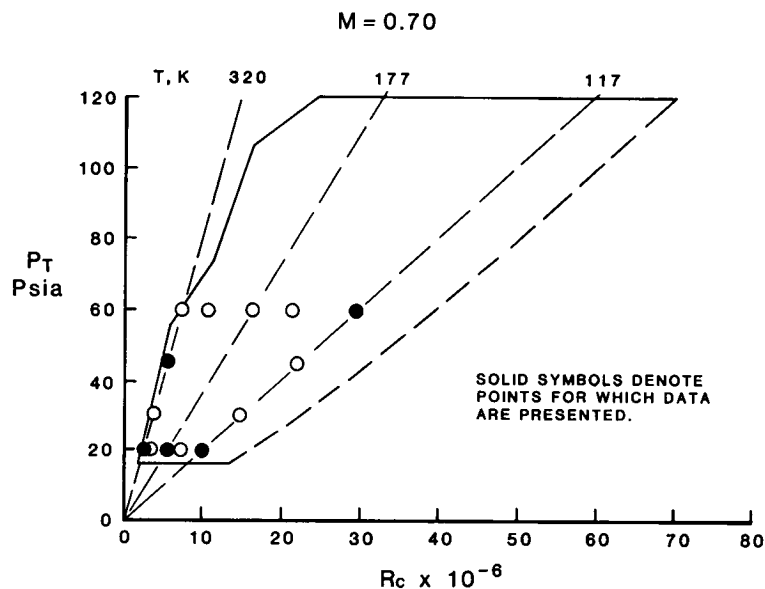


TEST ENVELOPE FOR MODEL INSTRUMENTATION CHECKOUT

For purposes of checking the effects of temperature on model instrumentation performance, it was desirable to have a condition where the flow would be sensitive to Reynolds number and the same test Reynolds number could be obtained at ambient and cryogenic conditions. The Pathfinder I model was used and tested over a Mach number range from 0.40 to 0.82. The test condition of temperature and pressure is shown in the accompanying figure for a Mach number of 0.70. A maximum chord Reynolds number of approximately 5 million was obtained in air at a temperature of 320K at 3 atm stagnation pressure and the same Reynolds number was obtained at 177K and 1.33 atm stagnation pressure. These results will be compared in subsequent figures. Additionally, data will be presented to show the effects of Reynolds number between 2.5 and 29.4 million by varying temperature from 320K to 117K at 1.33 atm stagnation pressure and then increasing pressure to 4 atm.

A Mach number of 0.70 was selected for analysis since any Reynolds number sensitive separation present on the airfoil would not be dominated by shock effects, and thus, would be less sensitive to any changes in model surface conditions that might occur during the test due to particles in the stream.

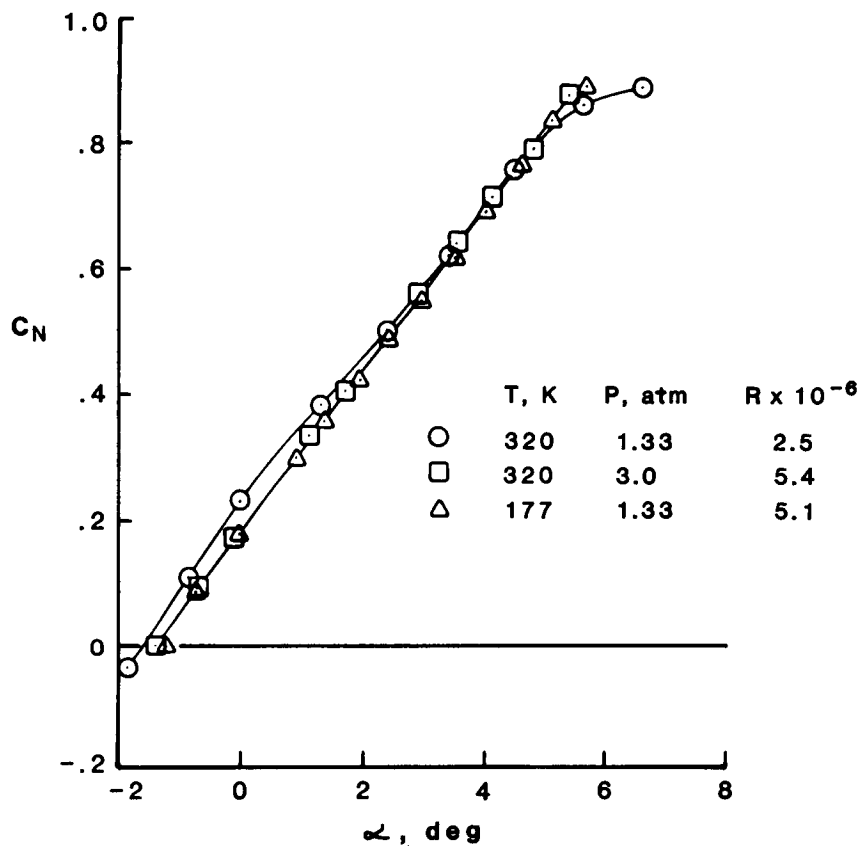
The internal strain gage balance used to measure model forces and moments was unheated. Temperature measurements were made at the bridges, and corrections to zeroes and sensitivities were applied. For this balance, zero shifts in axial force occurred during the test that were not experienced either during calibration or cryogenic checkout prior to the test. Therefore, drag data were not obtained. The zero shifts were repeatable in post test checks and further evaluation is continuing. Angle of attack and pressure instrumentation was maintained in a heated environment at all times.



EFFECT OF TEMPERATURE ON C_N VERSUS α MEASUREMENT

The accompanying figure shows the variation of normal force with angle of attack and indicates the same result is obtained at a constant Reynolds number for a temperature of both 320K and 177K. The data for a Reynolds number of 2.5 million based on model chord show the familiar characteristics of the supercritical wing tested at low Reynolds number. The nonlinearity of low angles of attack has generally been attributed to flow separation on the lower surface in the cusp region and, of course, trailing-edge separation is apparent at the highest angles of attack.

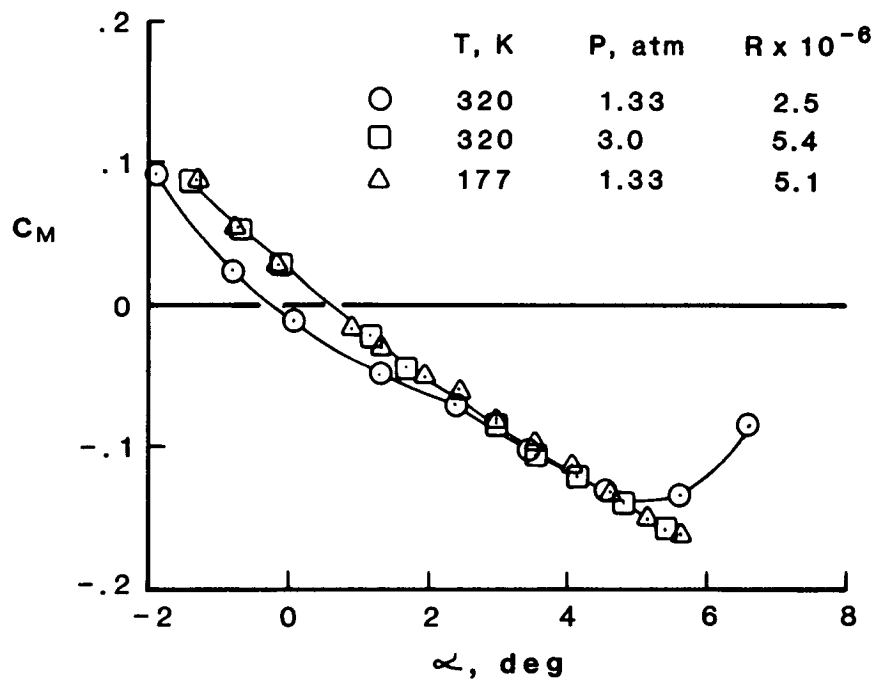
PATHFINDER I ; $M = 0.70$



EFFECT OF TEMPERATURE ON C_M VERSUS α MEASUREMENT

The accompanying figure illustrates the variation of pitching moment coefficient with angle of attack for essentially the same Reynolds number obtained at temperatures of 320K and 177K. The agreement is very good.

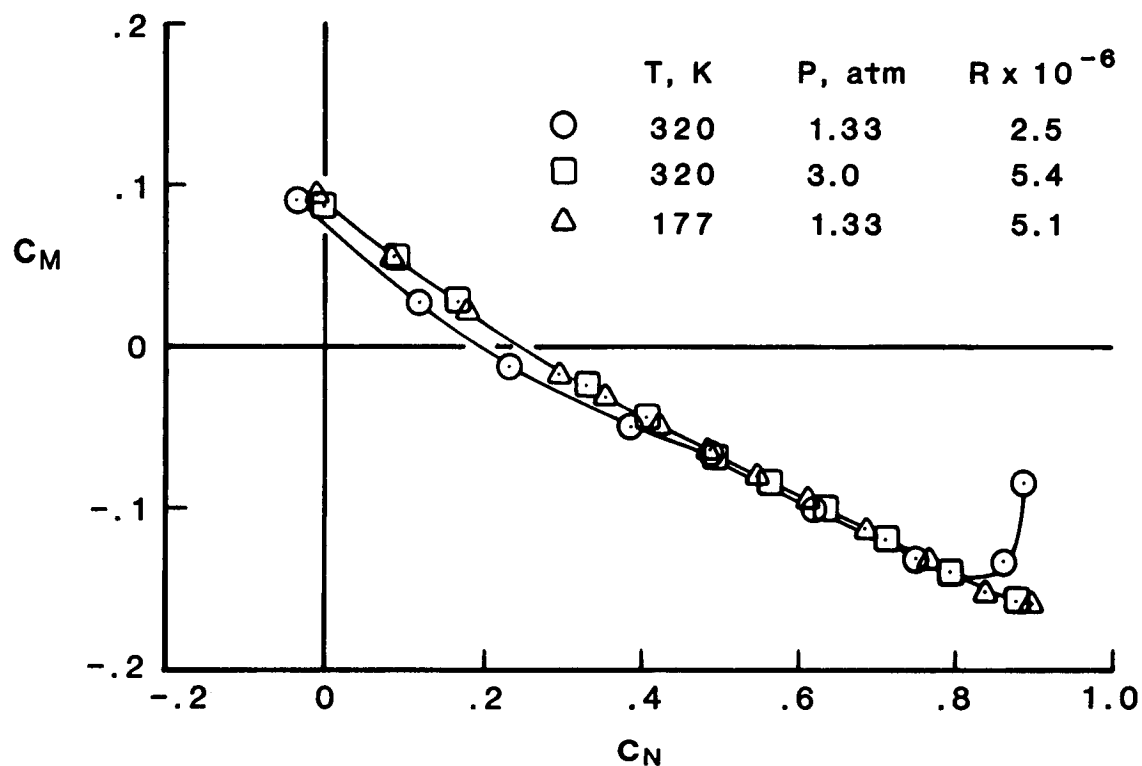
PATHFINDER I : $M = 0.70$



EFFECT OF TEMPERATURE ON C_M VERSUS C_N MEASUREMENT

The accompanying figure illustrates the variation of pitching moment coefficient with normal force coefficient for essentially the same Reynolds number obtained at temperatures of 320K and 177K. The agreement between the two conditions is very good.

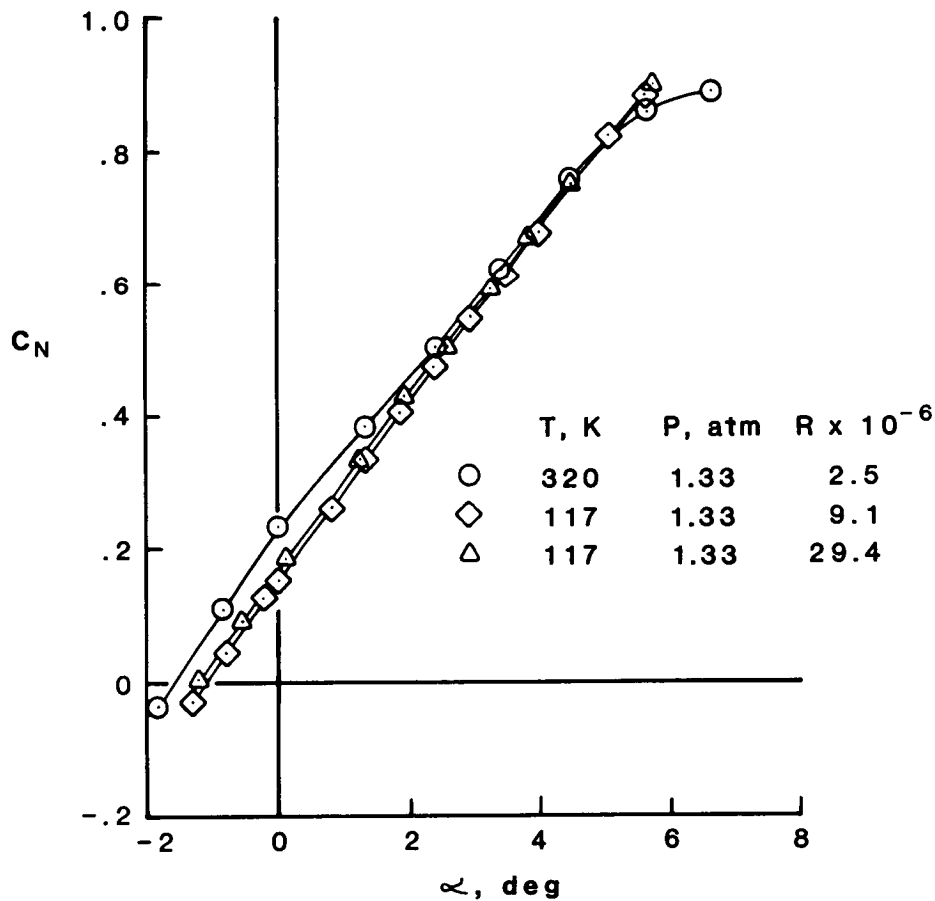
PATHFINDER I ; $M = 0.70$



EFFECT OF REYNOLDS NUMBER ON C_N VERSUS α

The accompanying figure illustrates the effect of Reynolds number on the variation of normal force coefficient with angle of attack for the Pathfinder I model. For this case, all of the effect of Reynolds number is obtained by 9 million. The small difference in angle of attack for a constant lift (approximately 0.1 degrees) between 9.1 and 29.4 million appears to be the result of a small shift in angle of attack zero. This is being evaluated.

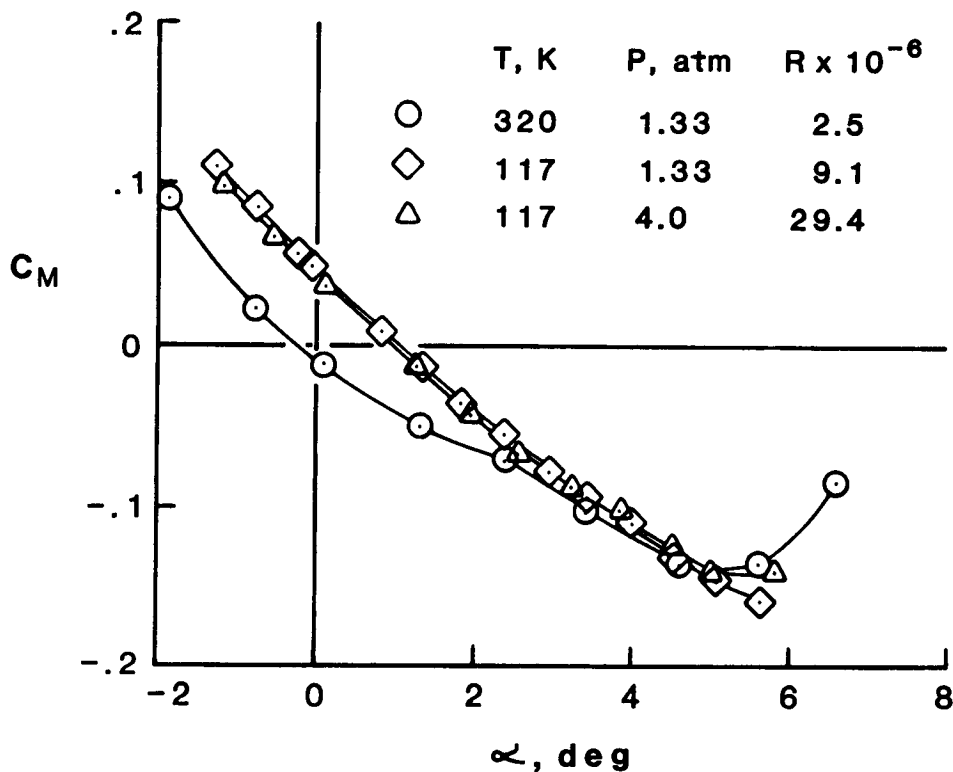
PATHFINDER I : $M = 0.70$



EFFECT OF REYNOLDS NUMBER ON C_M VERSUS α

The accompanying figure illustrates the effect of Reynolds number on the variation of pitching moment coefficient with angle of attack for the Pathfinder I model. As in the case of normal force, essentially all of the effect of Reynolds number is obtained by 9 million. These data also indicate a probable shift in angle of attack between the 9.1 and 29.4 million Reynolds number runs. At the highest angles of attack, a reduction in stability is indicated for the 29.4 million Reynolds number due to aeroelastic effects on the swept wing at 4 atm stagnation pressure.

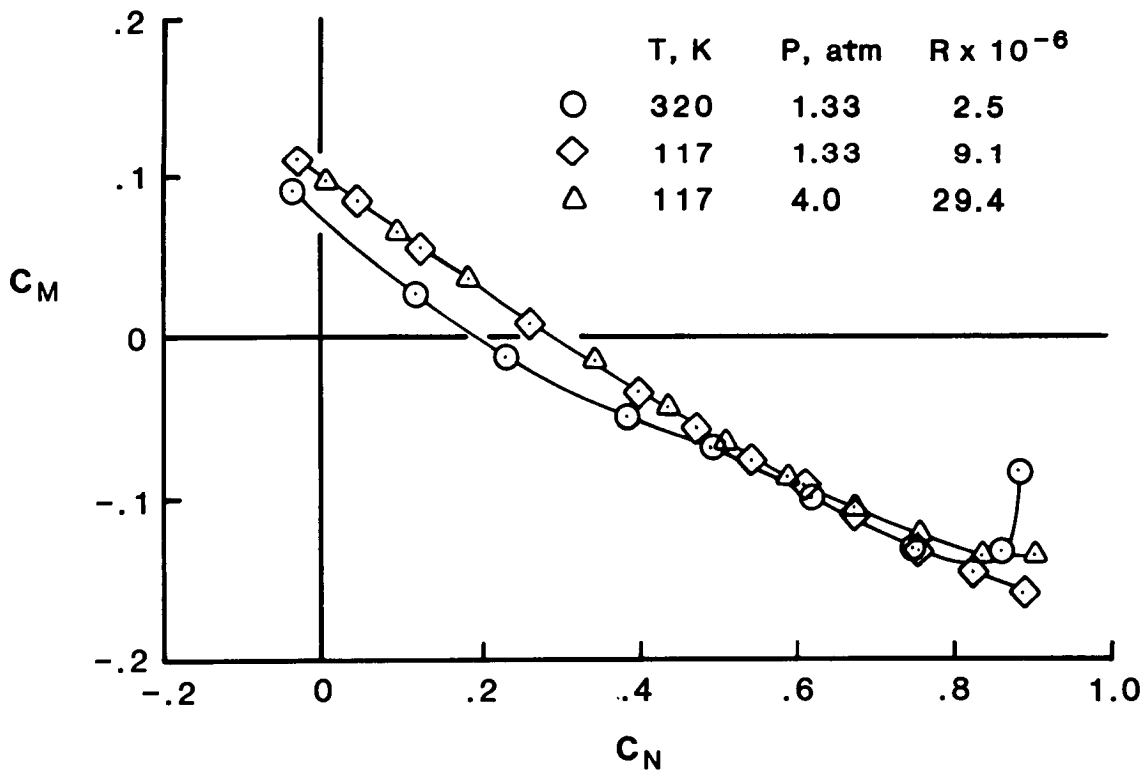
PATHFINDER I; $M = 0.7$



EFFECT OF REYNOLDS NUMBER ON C_M VERSUS C_N

The accompanying figure illustrates the effect of Reynolds number on the variation of pitching moment coefficient with normal force coefficient for the Pathfinder I model. The near perfect agreement between the data at 9.1 and 29.4 million Reynolds number indicates no change in load distribution between the two cases. This supports the earlier statements that the differences in normal force and moment with angle of attack are most likely due to a small shifts in angle of attack zero between the two runs. The reduction in stability due to aeroelastic effects is readily apparent for the case at 4 atm stagnation pressure.

PATHFINDER I; $M = 0.70$



SUMMARY

- o The NTF has been operated to design condition of 120 million Reynolds number at a Mach number of 1.0.
- o All systems have been checked out except plenum isolation valves; modifications are being made to heaters on the actuators.
- o Initial steady-state calibration indicates excellent steady flow characteristics.
- o The first test of the Pathfinder I model indicated significant Reynolds number effects.
- o Some effects of temperature on instrumentation were obtained. The cause of these effects is being evaluated.